Faculty Of Engineering

PACK CARBURIZING STUDY OF LOW CARBON STEEL THROUGH ACTIVATED CARBON

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Bachelor of Engineering with Honours
(Mechanical and Manufacturing Engineering)
2019

UNIVERSITI MALAYSIA Sarawak

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Final Year Project Report ☐

Masters ☐

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PACK CARBURIZING STUDY OF LOW(MILD) CARBON STEEL THROUGH ACTIVATED CARBON

MAUREEN ANAK TAMBI

A dissertation submitted in partial fulfillment

of the requirement for the degree of

Bachelor of Engineering with Honours

(Mechanical and Manufacturing Engineering)

Faculty of Engineering

Universiti Malaysia Sarawak

2019

To my beloved family and friends

ACKNOWLEDGEMENT

First and foremost, I would like to express my utmost gratitude to the Faculty if Engineering of Universiti Malaysia Sarawak (UNIMAS) for providing me the opportunity to conduct and complete my Final Year project (FYP) in order to gain experiences as an academic researcher and as a condition for graduating the degree. I would like to give my deepest respects and gratitude to my project supervisor, Professor Ir Dr. Amir Azam Khan for his time, effort, guidance, commitment, knowledge sharing and continuous support from the beginning towards the very end of my project.

Apart from that, without any hesitation, profound thanks to our laboratory technician, Mr.Sabariman and Mdm.Hazmiza Kontet for their assistance in technical advice and gathering material during the execution of this project. Without their generous assistance, I may not be able to complete my project for the past 14 weeks.

Next, most gracious thanks to my course-mate, Melvin Luat Anak Augustine Lubon and all of my friends for their insights, advice, and motivation when times are hard and everything seems so difficult to complete on time.

Last but not least, I would like to acknowledge the unpayable debt of gratitude that I owe to my family members who have always been there for me to give their countless support, encouragement, prayer and financial support.

ABSTRACT

The objectives of this research are to conduct a study on the effect of pack carburizing process through activated carbon with varying time and temperature on properties of the low carbon steel sample. The properties are represented by the results of Vickers hardness testing and also the Scanning Electron Microscopy (SEM) images of the microstructure. The surface hardness of the control sample was 121 Hv. The SEM image shows the presence of pearlite which contains both ferrite and cementite. The carburizing process was conducted in three different temperatures of 850, 900 and 950^{0}C. At each temperature, three samples were held at different carburizing times of 60, 120 and 240 minutes respectively. Once the carburizing process was accomplished, the sample was again been heated above the austenite temperature and rapidly quenched into the water bath. From the quenching process, the result shows that the sample which has been carburized at 950^{0}C and held for 240 minutes produced the highest surface hardness of 736 Hv. From the SEM images, this sample shows the highest amount of martensite (hard and brittle microstructure) was formed on its surface. All of the quenched samples then were further tempered at 550^{0}C and held for 60 minutes to reduce the brittleness. From the tempering process, the same samples produced the highest surface hardness of 411 Hv. The SEM image shows the formation of tempered martensite along with a sparsely distributed ferrite matrix. In addition, all of the results obtained was indicated a reduction in the surface hardness of all carburized tempered samples. However, the final surface hardness of all carburized samples is higher than the control sample (121 Hv).

ABSTRAK

Tujuan utama kajian ini dijalankan adalah untuk mempelakari kesan daripada eksperimen karburasi baja karbon dengan menggunakan pelbagai masa penahanan dan suhu karburasi. Ciri-ciri mekanikal daripada kesan karburasi ini akan ditentukan melalui mesin ujian kekerasan dan gambar struktur hasil daripada imbasan mikroskop elektron . Kekerasan permukaan sampel kawalan ialah 121 Hv. Hasil daripda imbasan mikroskop elektron, gambar telah menunjukkan struktur pearlite yang terhasil daripada gabungan anata ferrite dan juga cementite. Process karburasi telah dilalukan pada tiga suhu yang berbeza iaitu pada suhu 850, 900 dan 950^{o}C. Tiga sampel akan ditahan selama 60, 120 dan 240 minit pada setiap suhu yang berbeza, Setelah proses karburasi ini berjaya dilakukan,sampel sekali lagi akan dipanaskan sehinga mencapai suhu astenitasi dan selepas itu akan segeradisejukan ke dalam bekas yang mengandungi air (agen penyejuk). Hasil daripada process pelindapkejutan tersebut, keputusan menunjukan sampel yang telah dikarburasi pada suhu 950^{o}C dan ditahan selama 240 minit telah menghasilkan nilai kekerasan permukaan yang paling tinggi iaitu sebanyak 736 Hv. Hasil daripada imbasan mikroskop elektron telah menunjukkan penghasilakn struktur martensit (struktur yang sangat keras dan rapuh) di atas permukaan sampel tersebut. Sample sekali lagi dipanaskan pada suhu 550^{o}C dan ditahan selama 60 minit untuk menggurangkan kerapuhan pada sampel. Hasil daripada proses pemanasan tersebut, kekerasan permukaan sampel terlah berkurang daripada 736 Hv kepada 411 Hv. Hasil daripada imbasan gambar SEM menunjukkan struktur martensit yang telah dipanaskan telah merebak ke dalam matrik ferit. Process pemanasan semula sampel yang telah disejuk segera telah menunjukkan pengurangkan ke atas kekerasan permukaan pada semua sampel tang telah dikarburasi. Akan tetapi nilai kekerasan kesemua sampel masih lagi tinggi daripada kekerasan sampel kawalan (121 Hv)

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LIST OF ABBREVIATIONS

Al	Aluminium
Fe	Iron
Cu	Copper
C	Carbon
Ni	Nickel
Mo	Molybdenum
CO	Carbon monoxide
Mn	Manganese
SAE	Society of Automotive Engineers
AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Materials
HSLA	High Strength Low Alloy
BCC	Body Centered Cubic
FCC	Face Centered Cubic
NaCl	Sodium Chloride
$CaCl_2$	Calcium dichloride
NaOH	Sodium Hydroxide
SEM	Scanning Electron Microscopy
HV	Vickers Hardness Number

CHAPTER 1

INTRODUCTION

1.0 Introduction

In this chapter, it is consist of research background, the problem encounter regarding the low carbon steel, objectives of this research, scope of study , dissertation structure as well as the summary on this chapter.

1.1 Research Background

This research study deals with an experimental investigation on the pack carburizing study of low carbon steel (mild steel) through activated carbon. Before that, an introduction of the material will be briefly explained.

The development of civilization that we associate in all ages is due to the earth's material that played an important role (Science & Engineering, 2017). Metal that is generally ductile, good in conducting electricity and easy to shape can be classified into two types which are ferrous and non-ferrous. Ferrous is a group that mainly consisted of iron (Fe) and iron can be found in many industrialized countries and application. While non-ferrous defined as other metallic materials that do not contain any iron, for instance, aluminum (Al) and copper (Cu). By according to their own properties, all the elements that come from ferrous and non-ferrous metal can be classified into metals and non-metals. Basically, carbon steels come from the ferrous metal group.

Generally, steel is widely used because it has much practical application in every aspect of life, especially in the construction sector. Due to favorable properties, steel is considered the best among the widely used metals and alloys. Steel is defined as a metal alloy that consists of carbon and iron (A. S. Hassan & Technologiae, 2015). When there is no alloying element (nickel and chromium) in the microstructure, steel is called as carbon steel. Carbon steel only composed mainly two elements like iron and carbon with a little amount of manganese as an alloying element as well as other small quantity of residual element that affect the properties such as silicon and copper. According to their carbon content, it can be characterized into low, medium , high and as also very high carbon steel. Table 1.0 below shows the classification of the carbon steels that can be found generally:

Table 1.1: Classification of Carbon Steels

Type of Carbon Steel	Properties
Low Carbon (Mild) Steel	• Contains 0.01% to 0.25% of carbon content • Most common and readily available • Low cost • Ductile • Low tensile strength but easy to shape **Application:** Pipe, wire, drawing parts, automobile panel bodies
Medium Carbon Steel	• Contains 0.3% to 0.54% of carbon content • Good wear resistance • Able to balance its ductility and strength • Can be found in high mechanical properties parts **Application:** Car parts, cylinders, crankshaft and heat treated machine parts
High Carbon Steel	• Contains about 0.55% to 0.95% of carbon content • High tensile strength and hardness • Good wear resistance • Moderate ductility

	Application: Screwdrivers, hammers, wrenches, and high-strength wires
Very High Carbon Steel	• Has a composition of 0.96% to 2.1% of carbon content • A very strong material • It is produced to has a specific atomic and molecular structure • High strength, ductility and very hard • Good wear resistance

However, heat treatment of steel can be done based on their carbon content, consequently, it can increase the strength, wear resistance as well as to make the parts to be constructed in a readily-flexible state (A. S. Hassan & Technologiae, 2015). A good mechanical property means good hardenability of steels are needed in many industries nowadays (Astunkar & Bonde, 2013).

In this research study, it is focused on carburizing the low carbon steel through activated carbon. By referring to Table 1.0 above, low carbon (mild) steel contains about 0.01% to 0.25% of carbon content. This type of carbon steel is the most common type and it is readily available. Besides low in price, low carbon steel is ductile, low tensile strength and easy to shape (malleable). Low carbon steel can be found in many applications such as in pipe, wire, drawing parts as well as in automobile panel bodies. But due to it low in strength and slenderness problem that lead to breakage and cracks when the load is applied, it has become the major concern and there are several protective approaches in order to enhance its surface hardness.

In addition, according to Jaypuria, 2008, carbon steel will become harder, stronger, hard to weld but low ductility when the carbon content of carbon steel was increased. Thus, to prove this statement, the case hardening process has been introduced. Case hardening defined as an approach used to increase the hardness of the material surface while retaining its chemical composition relative to the core. The case hardening process can be classified into four types which are carbonitriding, cyaniding, carburizing and nitriding. Each case hardening process composed of a different method, material, and equipment used. The result of the case hardening process was influenced by few parameters such as the temperature, heat treatment period, quenching media as well as the rate of heating and cooling (Oyetunji, 2012).

In this research, it only focused on case carburizing of low carbon (mild) steel through activated carbon. Carburizing is the most common surface hardening technique. This process will involve the diffusion of carbon into low carbon steel in a carbon-rich environment to form a high carbon steel surface as well as increase the surface hardness of the material (Rashmi Ranjan Pandaa, Dr.A.M Mohantyb, 2014). The objective of performing the carburizing process to generate a good combination of mechanical properties like hardness, toughness, strength as well as a good wear resistance which is necessarily used in any application. Moreover, hardness, fatigue and wear strength of a material can be also be determined from certain case depth in carburizing (Astunkar & Bonde, 2013). Furthermore, there are two major influential parameters which are post heat treatment and pre-heat treatment processes. However, in this project, the carburizing temperature and the holding time will be taken as the manipulated parameters to observe the changes in microstructure as well as the surface hardness of the specimens.

1.2 Research Gap

In the previous time, the pack carburizing of low carbon steel has been carried out with different technique, time and temperature. Besides that, the previous research of pack carburizing of low carbon steel was done by using a different type of carburized or carbon additives. For instance, the bone buffalo charcoal (Arsyad & Asmal, 2018), the carbonized palm kernel shell (Oluwafemi, Oke, Otunniyi, & Aramide, 2015), melon and snail shell (Adzor, S. Abella | Ihom, P. Aondona | Edibo, 2018), cow bone (K. S. Hassan, 2015) and pomacea canaliculata lamarck shell powder (Soenoko, Siswanto, & Widodo, 2018). At the end of the result, different types of carburized media result in different value of surface hardness of low carbon steel.

However, in this research study, we are going to study and observe the effect of using the activated carbon (granules) towards the surface hardness and the arrangement of the microstructure of the low carbon steel as a result of pack carburizing process.

1.3 Problem Statement

Generally. low carbon steel has many advantages. Besides low in cost and high availability, low carbon steel having all the material properties that are compatible with many applications (O. R. Adetunji & Adegbola, 2015). As we can see, the demand on producing good material for some application is increasing gradually. For instance, in the automotive and construction sector, they really demand on a material that is able to stand with a certain situation or condition with a low manufacturing process cost. Thus, a material that is tough and soft should be produced, which means that the material that was able to possess high strength and good wear resistance.

In addition, there was inconsistency in case depth will happen during the case hardening process. Case depth is manipulated by the variable in carburizing temperature and time (Azri & Ahmad, 2010). However, there is a temperature limit in case hardening which means, the process is not necessarily required a very high temperature to increase the carbon diffusion rate. When the carburizing temperature is very high, the core of the material can be worse and consequently will affect the diffusion rate of carbon.

At the elevated temperature, the concentration of the element is distributed uniformly because the rate at which the diffusing element deposited on the specimen's surface is greater than the rate which the element is diffuse toward the steel's core. Consequently, this will cause the formation of chemical compounds like nitrides and carbides which lead to the brittleness of the surface layer. Since the carburizing process was involved in heating and cooling time, thus, it is hard to control the case depth and obviously, it is difficult to perform an accurate control of actual carburizing time and temperature.

1.4 Research Hypothesis

Generally, the carbon particles in the activated carbon are in the minute sizes. Due to the extremely small carbon particles size, thus, the activated carbon is expected that, when it is given enough energy, the minute carbon particles are able to diffuse faster and at the same time can diffuse to a deeper level compare to other types of carbon additives which have been used in the previous research of pack carburizing of low carbon steel. Therefore, for this case, the surface hardness of the low carbon steel can be improved because the martensite can be produced at multiple levels or layer of the surface of low carbon steel.

1.5 Project Aims and Objectives

This project is to study and investigate the effect of pack carburizing of low carbon (mild) steel through activated carbon. The objectives of this research as follows:

1. To produce a higher surface hardness of low carbon steels
2. To determine the effect of varying carburizing time and temperature towards surface hardness and arrangement of the microstructure by using the activated carbon
3. To analyze the effect of heat treatment on the transformation of the microstructure of carburized and uncarburized mild steel through heat treatment using activated carbon

1.6 Scope of The Project

This project aims to investigate the effect of pack carburizing towards the mechanical properties of low carbon (mild) steel which is resulting in the enhancement of the surface hardness and also the transformation in the microstructure. Before carrying out the pack carburizing experiment, some literature review study must be done in order to have a clear overview of this research from the beginning until the end.

Besides that, material preparation must be done before the experiment, for instance, preparation of a few amounts of activated carbon that will be put inside a steel container. The small sample (10mm×10mm×6mm) will be put inside a steel container. The sample will be carburized in a rich carbon atmosphere at a certain temperature (850^oC, 900^oC, 950^oC) for a different holding time (2 hours, 4 hours and 8 hours). During the carburization process, holding time will be taken as the variable parameter in order to observe the mechanical properties of low carbon steel.

In addition, water is chosen as the medium for the quenching process. Theoretically, the faster the cooling rate, the higher the hardness (in steel). Thus, water-quenched generally harder than oil-quenched. Generally, water has higher thermal conductivity and cooling rate compared with oil.

Furthermore, the transformation of microstructure, which means the differences in the arrangements of phases that will affect its original mechanical properties will occur after the carburization process. In order to prove this hypothesis, mechanical testing will be carried out. The specimens will perform the hardness test before and after the carburization by using Micro Vickers Hardness Tester. Moreover, the changes happen in the microstructure will be observed by using the Scanning Electron Microscopy (SEM)